Learning Goals:

- Visualize different models of the hydrogen atom.
- Explain the similarities for each model.
- Explain what experimental predictions each model makes.
- Explain why people believed in each model and why each historical model was inadequate.
- Explain the difference between the physical picture of the orbits and the energy level diagram of an electron.
- Gain a sense for how scientists build models.
- Engage in model building.

Multiple Choice questions:

Open the [Models of the Hydrogen Atom] simulation. Which aspects of this sim are showing observations and which are showing inferences?

Picture of atom: radio buttons for observation/inference
Movement of photons across the screen: radio buttons for observation/inference
Energy level diagram: radio buttons for observation/inference
Pattern on spectrometer: radio buttons for observation/inference

Long Answer questions:

In this long answer, we will ask you to discuss the observations and inferences that led to each new model of the atom. You may find the [Models of the Hydrogen Atom] and [Rutherford Scattering] simulations helpful for answering these questions. To give you a better idea of the kind of response we are looking for, we'll start with an example of the observations and inferences that led to the transition from the Billiard Ball model to the Plum Pudding model:

Example: Billiard Ball to Plum Pudding – Before Thomson, it was thought that atoms were indivisible chunks of matter with no internal structure. As discussed in section 37.4 of Knight's introductory physics textbook, Thomson observed that x-rays could ionize monatomic gasses. Based on this observation, he made the inference that atoms could be separated into a negative part and a positive part. Also, based on the observations that cathode rays could be converted to current and deflected by a magnetic field, he made the inference that cathode rays were made of negative charges, and therefore that the negative charges could be removed from the bulk of the atoms. He then developed a model of the atom in which little electrons were stuck in a big positive goo. Note that he had a lot of evidence for the electrons, but his model of the positive goo was based mainly on a lack of evidence: no one had ever observed positive charges being separated from the atom or observed any evidence of their structure, so he just assumed the positive charge was one big mass.

1. Plum Pudding to Classical Solar System – To answer this question, open the Rutherford Scattering simulation. This simulation gives a microscopic picture of Rutherford's famous experiment in which he shot alpha particles at a thin foil of gold. Based on Thomson's Plum Pudding model, how did Rutherford expect the alpha particles to behave when he shot them at the gold atoms? (To see this behavior, go to the "Plum Pudding Atom" panel of the simulation.) Why? What did he observe instead? (Go to the "Rutherford Atom" panel.) Based on his observations, what inference did Rutherford make about the distribution of positive charge in the atom?

2. Classical Solar System to Bohr – Open the Models of the Hydrogen Atom simulation. What observation can you make about the light detected by the spectrometer in experiment mode that Rutherford's solar system model is unable to explain? Based on this observation, what inferences did Bohr make about the nature of atoms? How was this inference able to explain the observation? There is also a simpler observation we can make, that atoms are stable and do not collapse in on themselves. How did the Bohr model address this observation?

3. Explain the relationship between the behavior of the electron in the picture of the atom and the energy level diagram for the Bohr model. As n gets larger, do the **orbits** get closer together or farther apart? Why? As n gets larger, do the **energy levels** get closer together or farther apart? Why?

4. Bohr to deBroglie – The deBroglie model is different from the previous models we have discussed in that it was based on a theoretical argument, rather than on experimental observations. (There is no experimental difference between the Bohr model and the deBroglie model!) What was the problem with the Bohr model that deBroglie sought to address? How did he address this problem? Do you think his argument was convincing? Would you have granted him a PhD for this argument? What later observations backed up his argument? How did these observations support his model?

5. How is deBroglie's view of the electron different from Bohr's view? What is the purpose of the three different views of the deBroglie electron in the Models of the Hydrogen Atom simulation? Which view do you find most useful for helping you understand the nature of the electron in this model? Why?

6. Name at least three observations scientists made that were either inconsistent with, or inadequately described by, the Bohr and deBroglie models. Discuss *how* the models were inadequate or inconsistent for each of these observations.

7. Describe the Schrodinger model of the atom (you may want to use the sim) and discuss how this model addressed each of the inconsistencies you listed in question 6.

8. Explain the relationship between the behavior of the electron in the picture of the atom and the energy level diagram for the Schrodinger model. Compare and contrast this explanation with the explanation you gave for the Bohr model in question 3.

9. Turn the simulation speed up to “fast” so that you can build up the spectrometer pattern more quickly. Then run the spectrometer for a minute for each model and take a snapshot with the camera button on the spectrometer. Compare the spectrometer readings for each model. Note that which photon happens to come in and excite the electron at any given moment is random, so pay attention to the overall pattern, not to small fluctuations in the numbers emitted. Explain, based on the spectrometer readings, the differences between each of the models. Which spectrometer reading is most similar to the spectrometer reading in Experiment mode? Why?